International Research Journal of Earth Sciences ISSN 2321 – 2527
Vol. **6(1),** 12-19, January **(2018)** *Int. Res. J. Earth Sci.*

Planning and development of towns in Togo: mapping of the Thermal status of Lomé and the formation of urban heat island

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Available online at: www.isca.in
Received 22nd November 2017, revised 20th January 2018, accepted 25th January 2018

Abstract

The world is undergoing a climate change followed by disastrous consequences. The warming of the planet that is growing shows this. Lomé, the capital of Togo, witnesses during these recent years, a sporadic wave of extreme heat, confirmed by meteorological data and by the work of many researchers that noted the growing of temperatures above the city. This research aimed to map the thermal status of the urban agglomeration of Lomé. Specifically, it is to determine the hottest area and the one at low temperature and to make a theoretical analysis in relation to the formation of the urban heat island in Lomé. The methodology used is based on records of daily temperatures of ambient air on twelve (12) observation posts installed in the urban agglomeration of Lomé. The collection of data from January 1 to December 31, 2016, preceded by the pre-collection of1st January to 30th June 2015 was directed at specific times of the day: 7AM; 1PM; 7PM; 12PM. The data processing by MS Excel revealed three (3) thermal areas. A low temperature area located on the outskirts and peripheral urban, an area with intermediate temperature at the center of Lomé Commune and a high temperature area that covers all the lower town of Lomé. The theoretical analysis states the gap in annual temperature average between downtown and the outskirts to 4°C. This gap exceeds 5°C during certain months. Therefore, Lomé houses phenomena of formation of momentary urban heat island (UHI).

Keywords: Identification, hot area, high temperature and urban heat island.

Introduction

In recent years, the scientific community agrees on the reality of climate change and global intensive warming. Current climate projections predict an amplification of warming already seen across the globe[1,2]. If emissions continue to rise at the current rate, impacts by the end of the century will include 2.6° to 4.8°C global temperature average, a rise of the level of the sea of 0.45 to 0.82 meter (m) and an intense disturbance of the weather conditions[3].

The observed warming reflected the consequences. This warming of the planet[4], for the fruit of what man has done as development for several years, without paying attention to the well-being of the environment. There was therefore a disruption of the balance of nature, especially through greenhouse gas emissions; effects of multiple human activities[2]. It is in this way that[5] argues that this global warming is likely to be amplified at the center of the cities with the specific microclimate of the area, this phenomenon is known as urban heat island (UHI). The phenomenon of formation of urban heat island (UHI) is defined as the temperature gap between urban and peri-urban areas and the surrounding rural areas. Indeed, the effects of the climate change are more felt in mineralized areas like urban circles where intense warming are create. To the number of the consequences, reports[6] must be noted an amplification of the phenomenon of urban heat island formation. This phenomenon highlights is mainly nocturnal, invisible, found by a demonstration of a heat which has impacts on health, ranging from cramps to heat syncope and heat exhaustion by the heat. It is a recurring phenomenon in developed countries.

However, nowadays, with the accentuated exhibition of the African continent to the vulnerability, to the thermal variability and the climate change, this phenomenon is growing in African cities. So according to Badameli A. and Dubreuil V.[7] the evolution of temperatures in West Africa is faster than global warming. Some works focused on the phenomenon of global climate change[8-9]. In this way have shown by their works an extreme variability and a decreased sharp in rainfall over the past decades. This is aggravated in cities with the interaction of multiple stress occurring at various levels with a low adaptive capacity of the people. Sub-Saharan Africa is not an exception to be part of today's most urbanized regions of the world essentially dominated initially by national capitals[10].

Regarding the city of Lomé, capital of Togo, it appears as a beautiful illustration of a fast urbanization. Rapid urbanization of Lomé takes an urban sprawl in three steps, which led to the formation of a large urbanized area that continues to populate and extend[11]. In recent years, the development of this set is materialized by a strong occupation of the floor, which focuses on various facilities including road infrastructure, in addition to the erection of massive and compact buildings after the destruction of large areas of vegetation[12].

With the floor more and more naked, Lomé is facing a rise of temperature average, and speed up since the year 1980. Indeed[7] show by their works that temperature of Lomé, in perpetual growth, increased to 1.6°C between 1961 and 2010. Several authors like[13] even speak of the passage of waves of overwhelming heat to express the Status of global warming of the city.

There are many authors who have written on the gradual increase of the temperature in Lomé but their works could not specify the hottest areas and the correlation between rapid urbanization and the risk of formation of urban heat island phenomenon (UHI) in Lomé[7,13].

In-the matter of the current situation, it is important to ask about the thermal Status in the urban agglomeration of Lomé. These increasingly strong sensational heat waves, would not be an illustration of the phenomenon of urban heat island (UHI)? It is to answer these questions that this study is carried out with aims to map the thermal status of the city of Lomé. This is mainly to determine the hottest area in opposition to one at a low temperature and to do a theoretical analysis on the phenomena of the formation of urban heat island in Lomé.

Materials and methods

Presentation of the study area: The Greater Lomé (Figure-1) located between 6°8" and 6°11" latitude North and 1°11" and 1°18 East longitude, covers the commune and the prefecture of Golf and spans on 152 neighborhoods with an area of 280 km^2.

Physical characteristic of the area of study: Topography and soils of Lomé revealed from the coast inward: i. A sandy cordon put in place by littoral drift West-East[14]. ii. Flood depression that works as a pool of storage of flood and alluvium[15]. iii. A land of bar tray that consists of arable clay-sandy soils.

The area of study has a Guinean subequatorial climate characterized by four (4) alternating seasons: a long dry season (November to mid-March), a short dry season (mid-July to August), a longrainy season (mid-March to mid-July) and a short rainy season (September to October).

The hydrographic network of the Maritime Region, which homes Lomé is characterized by three (03) water courses (Mono, Zio, Haho), rivers of less importance and a Beninese and Togolese lagoon complex[16].

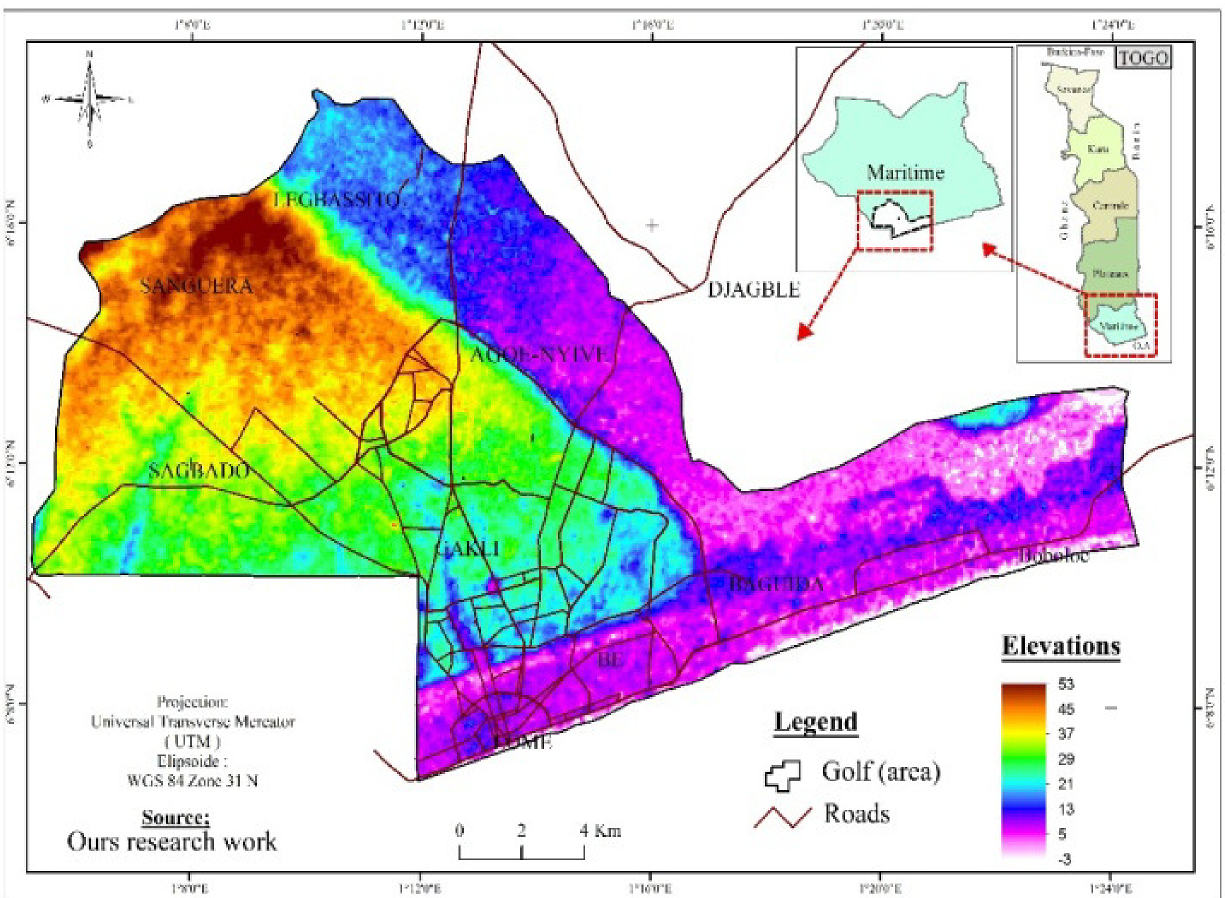

Figure-1: Location of the study area.

The coastal plain of South Togo is dominated by a mosaic of disparate patched forest, the anthropisees savannahs, fooling savannahs and prairies, the littoral of the relics of sacred thicketed forests, Fallows, crops, plantations and a specific formation: mangroves[17-20.]

Socio-economic aspects: In 2010, the population of Lomé is estimated at 1 447 660 inhabitants[21], with a rate of natural increase of 2.88%. The city of Lomé homes 62, 64% or 23.4% of the total population of Togo. It is the center of the economy of the country, where sit more than 95% of the industrial activities of the country[22]. It concentrated more than 60% of commercial activities and produces more than 60 percent of the gross domestic product (GDP)[22].

Data collection: There are several ways to know the thermal status of an environment. The methodology used in this study is based on measures **in-situ** using fixed sensors placed at locations determined by a stratified sampling .Beforehand, the urban agglomeration of Lomé has been divide into three (3) territories (T1; T2 and T3). The first territory covers Lomé Commune without outlying areas; the second covers the suburbs until the outlying townships located in the prefecture of Golf; and finally the third territory from the peripheries of the cantons towards the river zio; borderline of the prefecture of zio with that of Golf. The concentration of the population and land use criterion is the base of this data collection. These territories are considered as areas of enumeration. This temperature reading is from two among the three areas.

These surveys have been conducted four (4) times during the day: at 7AM, 1PM, 7PM and 12PM. The used approach is hypotetico-deductive approach that checks the proposed hypothesis. The same approach has been used in Vancouver in Canada but with a shade. In Vancouver, the experience was performed using a vehicle equipped with an insulated and ventilated of copper-constantan thermocouple mounted in a tube. It gave the possibility of automatic recording of temperatures on several points without interruption on the road. However, the analysis looked only on 59 points in order to simplify processing[23].

As the temperature readings will be made on a long-term, points must be stable to forbid any changes of position during the period of record. Thus, the choice is focused on points of Drugstores in Lomé, the points that are permanently stable and geographically well distributed between districts. So, an identification of the number of observation points of temperature was made. A number of 159 points are identified. Based on the formula of Schwartz ($N=eZ^2pq/i^2$) below, a sample of 12 points was selected[24].

$$n = \frac{1,96^2 \times p(1-p)\times(1+t)\times f}{h\times(p\times e)^2}$$

Where: n=sample; p=the number of observation points; t= no response rate; h=average size of observation points; f=effect of cluster; e=error of precision.

Stratified sampling to two level helped distribute points on the study area. A buffer of five hundred (500) meters was created around each point to keep a reasonable distance between observation points.

The data collection was preceded by a pre-collection from January 1, to June 30, 2015. This allowed having a summary status of the thermal variations before data collection itself, carried out from January 1 to December 31, 2016. It is based on a reading and recording the temperatures displayed on the screens outside Drugstores. These measurement points serve as initial brand in the analytical work[23]. The ambient air temperatures only were taken into account in this study.

Thermometers used are those incorporated inside the emblems of Drugstores. Outdoor screens of illuminated signs display in LED, characterized by a high resolution, visible at short distance with sensors of light located on the front of the device. These sensors display room temperature from the determination of the Status and the amount of ambient light that prevails in a place and at a given time (Sun, clouds, evening, night, and shadow). The trend today is the use of LED displays for specific values of climate parameters.

Table-1: Details of the temperatures observation Points.

		Coordonnées des Points d'observation des températures											
		Pot 1	Pot 2	Pot 3	Pot 4	Pot 5	Pot 6	Pot 7	Pot 8	Pot 9	Pot 10	Pot 11	Pot 12
Geographical details	X	307702	305972	303905	308405	301361	301197	303509	305163	298717	300295	299593	295712
	Y	680326	679003	678582	681633	676810	679796	682164	685154	682970	685795	687517	684524

Data processing and analysis: The observation points were geo referenced by Garmin GPS receiver (Etrex 30) to coordinate decision-making, but the transfer of data is done using DNGARMING software. The MS Excel program helped to do statistical calculations, the design of tables and graphs. Indeed several files are created and organized monthly. In addition, the formula of the arithmetic average below has been used to calculate all thermal averages[25]. We relied on the recommendations contained in the climatological practices manual for the method of calculating the daily temperature average. This method does not offer the best approximation from the statistical point of view, but its systematic use satisfies the comparison of the normal criteria. It is how temperatures average (Tmoy) were calculated. It is the daily average, the monthly average then the annual average of each observation post. A classification from the smallest to the largest of the annual averages was made.

A chart of thermal variation materialized on a map after regrouping the similar temperature by zones and delimitation of that area. The ArcGIS Desktop 10.4 softward has been used for SIG applications and the production of maps.

$$Tm = \frac{\sum (t1+t2 \ldots tn)}{n}$$

Results and discussion

Thermal averages and their monthly changes: Every month have a typical thermal variation according to the annual seasons. Temperature averages vary according to different reading time (Table-2). The differences between the highest temperatures and the lowest in the same time slots, on the entire city, vary between 2° and 4°C.

Representation of the evolution of temperatures by areas in the city of Lomé: Calculated thermal averages show three (3) distinctive areas of temperature changes: higher temperatures area (Z1), the area of the intermediate temperatures (Z2) and the area of low temperatures (Z3). On the figure (Figure-2), we observe almost a parallelism between the lines Z1 and Z2. High temperatures in January gradually decrease up to their lowest level in August. This month is the freshest seasonal month in Lomé with the presence of the Rainy season. These curves rise together around the month of January of the following year.

Table-2: Summary of the monthly averages of temperature by area within the year 2016.

	7H 00				13H 00				19H 00				00H 00				Moy mensuelle			
	Z_1	Z_2	Z_3	Δt	Z_1	Z_2	Z_3	Δt	Z_1	Z_2	Z_3	Δt	Z_1	Z_2	Z_3	Δt	Z_1	Z_2	Z_3	Δt
January	32	30	28	4	38	36	34	4	36	34	32	4	33	32	30	3	35	33	31	4
February	32	31	29	3	38	36	35	3	35	33	32	3	34	32	31	3	35	33	32	3
March	32	31	29	3	38	37	35	3	36	34	33	3	34	32	31	4	35	34	32	3
April	29	27	26	3	39	37	36	3	34	32	32	3	32	29	29	3	34	32	31	3
May	29	28	26	3	38	37	35	3	33	32	31	3	30	31	28	2	33	32	30	3
June	26	25	24	2	35	34	33	2	31	30	29	2	29	28	26	3	30	29	28	2
July	25	23	21	4	34	32	30	4	30	28	26	4	27	26	23	4	29	27	25	4
August	25	23	21	4	33	31	29	4	29	28	25	4	27	25	23	3	29	27	25	4
September	25	23	21	4	35	33	31	4	30	28	26	4	27	26	24	4	30	28	26	4
October	26	24	22	4	36	34	32	4	31	29	27	4	29	27	25	4	31	29	27	4
November	27	25	23	4	38	36	33	4	32	30	28	4	30	28	26	4	32	30	28	4
Décember	34	32	30	4	37	35	33	4	36	34	32	4	35	33	31	4	36	34	32	4

In zone1, temperatures range from 28° to 35°C. Intermediate temperatures in zone 2, vary from 26° to 34°C. As for zone 3 the variation is from 26 to 32°C (Figure-2). Zone 1 is the warmest. All information related to this area are obtained by a spatial representation on the study area.

Spatial representation of the thermal Status by area in the city of Lomé: The spatial representation of the results shows that the hottest zone is found on the coast, commonly named the lower town of Lomé (Figure-3). Thus, that confirms the hypothesis of the research. However, it should be noted that the coloration of the map is global and limits lines are imaginary according to the proximity of the installed positions. There are pockets of variation that could change this color that is not fixed.

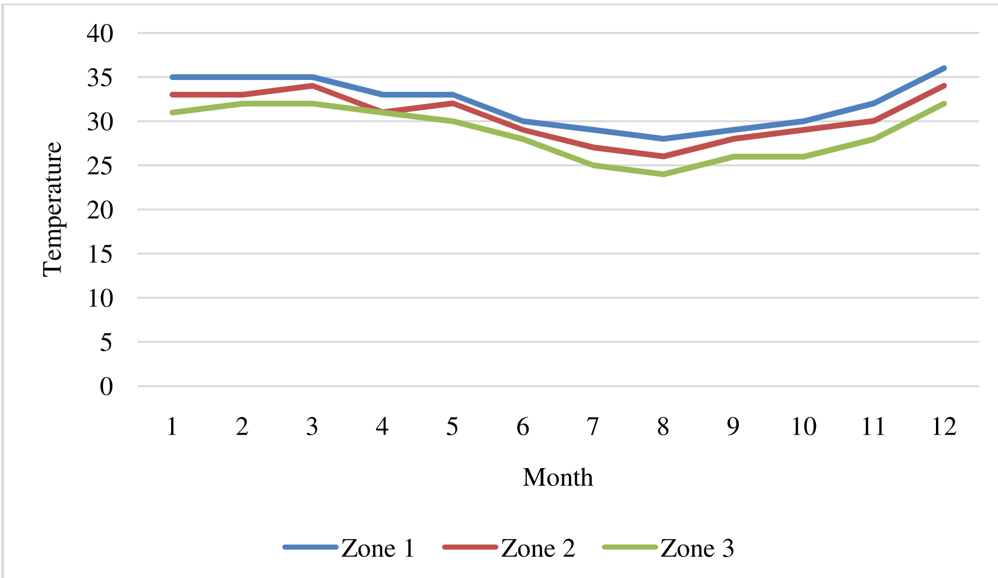

Figure-2: Thermal Variation in Lomé.

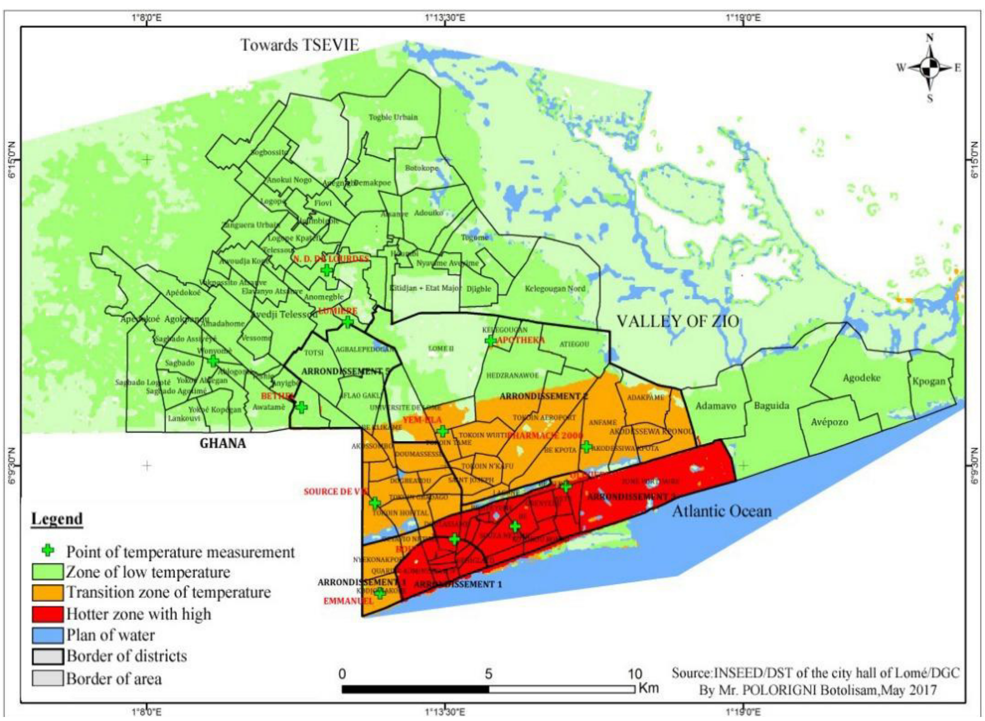

Figure-3: Thermal Variation in Lomé based on areas.

The lower town should not be the hottest area taking into account its geographical location, framed by two bodies of water including the Atlantic Ocean and the lagoon system that runs through coastal cities like Abidjan, Accra, Lomé, Cotonou, Lagos. Two bodies of water that could bring some freshness to the shoreline taking into account natural benefits of evaporation and evapotranspiration of a body of water in an environment. Face to these results, some tracks for thought on the causes of global warming of the coast can be advanced. These ideas are grouped in two aspects: i. On the geographical or topographical plan, the level of the sea at the coast is higher than the level of the lower town of Lomé. The topography of the coast shows that the sea level is higher than the floor of the lower town. An elevation of the masses of fresh air that catches the tray away from the city, flies over the lower town which has peaks and compact massive sets erected along the coast. This area is therefore less nourished by the moving wind. Also is there any evidence that the direction of the prevailing winds is Southeast to Northwest. What could cause distance between the plateau and the winds from the lagoon system. Thus is created a kind of greenhouse warming with anthropogenic activities. ii. In anthropogenic terms, human action continues to develop buildings in height on the coast which's level can complicate the passages of air masses that tend to blow on the lower town. In addition, a significant part of this warming is explained in the concentration of activities including businesses, services and industries, covering the majority of channels, the mass occupation of the floor by the buildings, the worrying disappearance without replacement of the vegetation and the concentration of the population on the coast that is the center of business.

Discussion: Analysis in connection with the phenomenon of the formation of urban heat island: The temperature measurement method **'in situ'** has been effective to determine the hot zone and the cooler area of Lomé. It is even more effective when it is associated to modern techniques including an instrumented vehicle. Our research results show a thermal average gap of 3°C between monthly average temperatures in zone 1 and the zone 3. However, the gap between the monthly temperature average recorded at 7 PM refers to a gap of 4°C. The gap of 4°C between downtown and the outskirts of Lomé is already worrying. Several authors believe that with a gap of 4°C in temperature, we can talk about presence of urban heat island. Some go further stating that more the urbanization is dense, more the urban heat island (UHI) are powerful. An aerial view of the zone 1 on the coastline of the lower town of Lomé shows a dense concentration of occupation marked by a highly built-up.

Regarding all that above, the presence of urban heat island in Lomé is real. It should be noted however that the corridors of canyons streets wind of the coast has not been object of this study. This one must be part of another study to highlight the identification of UHI zones. At the heart of these studies the exposure of the streets, the direction of the winds in the streets and the heights of the buildings lining the streets, must be the objectives to be achieved.

The urban agglomeration of Lomé and the formation of UHI: Results of the study show that in Lomé, the belt between the lagoon system and the coast bordered by the Atlantic Ocean is particularly warmer than the plateau and the northern limits of the greater Lomé. Monthly temperatures average close to 35°C. However, there are daily peaks ranging up to 40°C during certain months mainly in December and January according to the records of investigations. These results are similar to those made by Achour-Bouakkaz N.[23] on the Algeria which is also boarded by the sea. Indeed, he notes that the influence of the sea is supposed to cool temperatures at the level of the city of Alger but unfortunately it is not the case. He says that although there are other factors of influence that affect the minimum, in the specific case, he insists that it is the daily heat stored by the surface open to the sky (roofs and streets) which is at the origin of this gap at the level of Alger port. In addition, there is a formation of urban heat island when comparing our results with the findings of Liébard A. and De Herde A.[26]. They estimated at 3.5°C the temperature gap between the surroundings and a Center-City less greened, and Oke T.R.[27] who fix the temperature gap between the periphery and the downtown housing an urban heat island between 4 and 10°C.

Heat islands are defined as the difference of temperature of the air between the city and its surroundings[6]. The intensity of this phenomenon varies according to cities based on their climate, their topography, their population, their morphology and their activities. There are many urban parameters which are involved in the formation of the heat island. Mainly, it is the urban morphology, the specific physical properties of urban materials, lack of evapotranspiration, emissions of anthropogenic heat[28].

This phenomenon is accentuated by the urban growth, which is a potential modifier for the climatic conditions in a given region by extension of the apartment buildings, the significant increase in the number of cars, the lack of vegetation, waterproofing of spaces[4].

The density of the population influences the intensity of an UHI in the study area[27]. It is in this context that a relationship is established between the size of the city and the intensity of the UHI. The larger of the population and the size of the city, increase the intensity of the UHI. The temperature gap is according to the logarithm of the population: $\Delta T = 2,01 \text{Log} P - 4,06$ [27]; when applying this formula, the ΔT temperature gap is 8.35°C for the greater Lomé.

The urban agglomeration of Lomé and the management of the hot areas: The natural variability of the elements of the climate in the region of bas Togo makes difficult the detection of climate change. However, several authors through studies have shown that there is indeed a change in the climate not only in Lomé, but also at the regional level and at the level of other cities in Togo[13]. It appears in these studies that there is a clear evolution of the annual variations of temperatures. Thus, the thermal growth on the plain of southern Togo varies from 1 to 1.6°C between 1961 and 2010[7]. On 38 years of observation (1961-1998) in Lomé, rainfall decrease to 12.10% over the Littoral. This demonstrates a real trend to climate change in the future[13].

For this purpose, a set of climate scenarios must be simulate, in order to project into the future a possible evolution of the coastal climate in Lomé on the horizon 2050. If no action is taken to reduce the climate change, the temperatures could climb to more than 2°C[13]. This is related to several factors including large-scale disappearance of vegetation cover, the mass of anthropogenic activities, the mineralization of the city and the population explosion. Zone 1 would be more exposed to an intense warming leading to the risk of heat wave, a public health problem. Therefore, it is important to act quickly to put down by a new design of urban management and planning practice. In this case, the choice of indicators of urban growth parameters monitoring is necessary. These parameters must be determined with reference values in order to develop a strategy for their control and management.

The current trend is to encourage and increase the planting of trees to create shade and increase the virtues of absorption of the Sun's rays. It is shown that vegetation affects the urban environment by transpiration from the leaves, by providing shade and blockage of the Sun's rays[29]. The lack of vegetation increases the magnitude of the UHI. It is also important to develop water bodies to help Lomé for cooling by evaporation and evapotranspiration.

Conclusion

This study relied on the method of temperatures measurement **in-situ**, which has proved very effective in the determination of the hottest area of the urban agglomeration of Lomé. The temperature records for a year on the installed 12 posts reveal a hot area, and an area of low temperatures separated by a so-called intermediate transition area. The hot zone (Z1) coincides with the lower town of Lomé, located on the coast. An abnormal situation on a critically background of a phenomenon whose causes are more anthropic action than natural. From this area, it is observed a gradual decrease in temperature following the gradient Center-city to the northern outskirts of the city. According to the results, a gap of annual temperature average varying from 3° to 4°C is recorded between the coastline and the surrounding. However, the difference between the daily thermal averages, taken in isolation, explains a formation of urban heat island in Lomé. It is important to search ways of current planning which are in a status of steady warming, prone to this phenomenon.

Special attention of decision makers to the thermal variation of Lomé is suggested. This should be done as planting trees and creating urban forest programs.

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